A
Synopsis
on

Extraction of Nanocrystalline Cellulose (NCC) from Post-Industrial Cotton Waste for Reinforcing Starch-Based Biodegradable Films

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University Department of Chemistry

B. N. Mandal University, Madhepura

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Submitted by

Aman Awishkar
Roll- CHE-01/23 Mob-
8709802582

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WORK PLAN

A. PURPOSE AND NEED OF STUDY :

The textile industry is one of the largest polluters globally, generating massive quantities of pre-consumer (spinning/cutting waste) and post-consumer waste.

The Problem: While cotton is biodegradable, textile waste accumulating in landfills generates methane. Furthermore, "downcycling" cotton into rags or insulation underutilizes its potential. Cotton is unique because it is nearly 90-95% pure cellulose, making it a far superior feedstock for advanced materials than wood (which is heavily lignified).

The Need: There is a critical need to upcycle this waste into high- performance materials. This study aims to isolate Nanocrystalline Cellulose (NCC)—a material with strength properties comparable to Kevlar—from cotton waste to reinforce weak bioplastics (like starch) for packaging applications.

DETAILS OF THE PROJECT WITH

CHAPTERIZATION

Chapter 1: Introduction

Status of the global textile waste crisis.
Properties of cotton fibers vs. lignocellulosic biomass.Concept of Nanocomposites in green chemistry.

Chapter 2: Literature Review

Review of acid hydrolysis methods for cellulose extraction.Previous studies on starch/cellulose composites.
Gaps in utilizing dyed or impure cotton waste streams.

Chapter 3: Materials and Methods

Collection of waste (Combings/Noils from spinning mills).Chemical purification (Scouring and Bleaching).
Acid Hydrolysis process parameters.Film casting techniques.

Chapter 4: Results and Discussion

Crystallinity Index analysis (XRD).
Morphological study (TEM/SEM).
Mechanical and Thermal performance of the composite films.

Chapter 5: Biodegradation Studies

Soil burial testing protocols. Solubility and water absorption rates.

Chapter 6: Conclusion

Viability of cotton waste as a source for nanomaterials.

HYPOTHESIS

The ongoing work centers on the mechanical and barrier properties of the starch films. It focusing on how NCC, sourced from cotton waste, formshydrogen bonds and creates a reinforcing network. We expect this to drastically improve tensile strength and the water vapor barrier of the resulting bioplastic. This is a practical step towards waste valorization.

The core is using post-industrial cotton waste to create NCC filler for starch films, enhancing strength. The focus is on a rigid network formation, leveraging NCC's properties to overcome starch film limitations. The novelty lies in the material's source, improving its functionality and maintaining biodegradability.

Phase 1: Pre-treatment of Cotton Waste

Objective: To remove non-cellulosic impurities (dyes, sizing agents, oils, hemicellulose) and isolate pure cellulose.

Mechanical Size Reduction: Cut the post-industrial cotton waste into small pieces (approx. 5 \times 5 mm) to increase the surface area.

Alkali Treatment (Scouring):

Prepare a 2-4% sodium hydroxide (NaOH) solution.

Immerse the cotton waste in the solution at a ratio of 1:20 (solid:liquid).

Boil under reflux at (80-100)℃ for 2–4 hours under continuous mechanicalstirring.

Wash the residue thoroughly with distilled water until the pH is neutral.Note: This step removes hemicellulose, waxes, and surface oils.

We will find some another alternative as on-going work to more expected result.

METHODOLOGY

The study will be conducted in three distinct stages:Stage I: Purification of Cotton Waste

Scouring: The cotton waste will be treated with Sodium Hydroxide (NaOH) at boiling temperature to remove waxes, pectin, and non-cellulosic impurities.

Bleaching: Treatment with Hydrogen Peroxide (H_2O_2) to remove natural coloration and whiten the fibers.

Stage II: Synthesis of Nanocrystalline Cellulose (NCC)

Acid Hydrolysis: The purified cellulose will undergo controlled hydrolysis using Sulfuric Acid (H_2SO_4, 64% wt) at 45°C.

Mechanism: The acid attacks the amorphous (disordered) regions of thecellulose polymer chains, leaving behind the highly crystalline, rod-like rigid parts (the nanocrystals).

Dialysis: The resulting suspension will be dialyzed against distilled water toremove excess acid until neutral pH is achieved.

Sonication: To disperse the nanocrystals and prevent aggregation.

Stage III: Biocomposite Fabrication & Testing

Matrix Preparation: Thermoplastic Starch (TPS) will be prepared using cornstarch and glycerol (plasticizer).

Casting: The Cotton-NCC suspension will be mixed with TPS in varyingconcentrations (1%, 3%, 5%) and solution-cast into petri dishes.

Analysis:

Crystallinity: Calculated using X-Ray Diffraction (XRD) using the Segalmethod:

Where " I" is the peak intensity of crystalline plane and " I" is the intensity of the amorphous background.

Morphology: Transmission Electron Microscopy (TEM) to visualize the aspectratio of the extracted nanocrystals.

BIBLIOGRAPHY

Sathasivam, R., & Haris, M. (2020). "Upcycling of cotton waste into nanocellulose: Process optimization and characterization." Carbohydrate Polymers, 240, 116346.

Jordan, J. et al. (2019). "Cellulose nanocomposites: A review from the perspective of the source material." Journal of Applied Polymer Science,136(30), 478-490.

Wang, S., et al. (2018). "Preparation of nanocrystalline cellulose from cotton linter and its application in starch films." Industrial Crops and Products, 121, 230-238.

Standard Protocols:

ASTM D638: Standard Test Method for Tensile Properties of Plastics.

ASTM D5338: Standard Test Method for Determining Aerobic Biodegradationof Plastic Materials.